Scientific Research

National Aeronautics and Space Administration

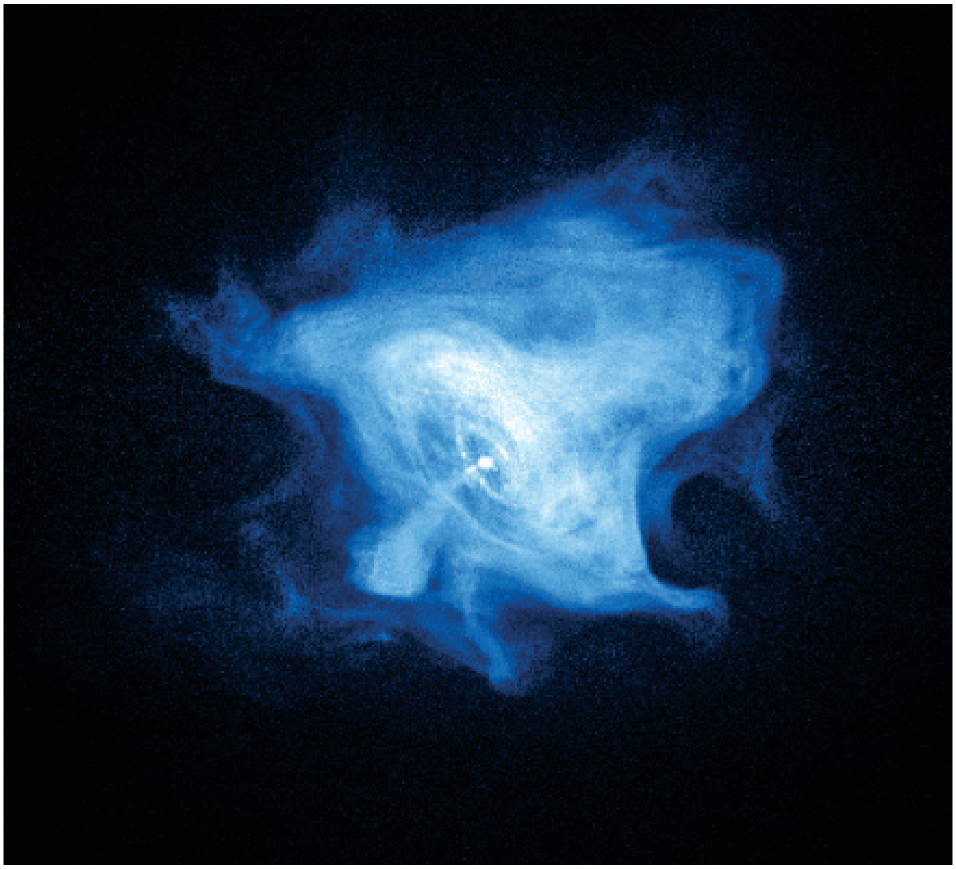
High-Energy Astrophysics

Revealing the Universe

Scientists and engineers at Marshall Space Flight Center are making significant contributions to humankind's understanding of the universe through work on space telescope missions focused on x-rays, gamma rays, and cosmic rays. Marshall optical engineers and scientists work collaboratively to design, test, and integrate high-energy astrophysics instruments. The Center also has been involved in the science, engineering, integration, and testing of three of NASA's Great Observatories, and continues to support development of next-generation space telescopes such as the James Webb Space Telescope.

At-A-Glance:

Marshall Space Flight Center pairs its scientists and optics systems for highly focused X-ray astrophysics mission and instrument design and large systems integration, contributing to world-class science capabilities for NASA.



This image, taken by Chandra as part of a campaign to locate a source of gamma-ray flares, gives the first clear view of the faint boundary of the Crab Nebula's X-ray-emitting pulsar wind nebula.

Expertise

Team members conduct panchromatic studies of star-forming regions and their impact on the growth and evolution of nearby galaxies, study gamma-ray bursts—the most distant and powerful explosions in the universe, and expand the scientific capabilities needed to reliably model many of the basic reaction processes for cosmic rays and solar energetic particles.

In recent years, researchers in Marshall's astrophysics group have published over 140 papers in SPIE Proceedings (optics and instruments) or in refereed journals (primarily astrophysical research). These include:

- 25 papers on technology advances and future mission concepts.
- 30 papers on x-ray mirror and detector design, performance, and fabrication.
- 34 papers on clusters of galaxies, including numerous South Pole Telescope results.
- 20 papers on the Crab nebula, Galactic and extragalactic X-ray sources.

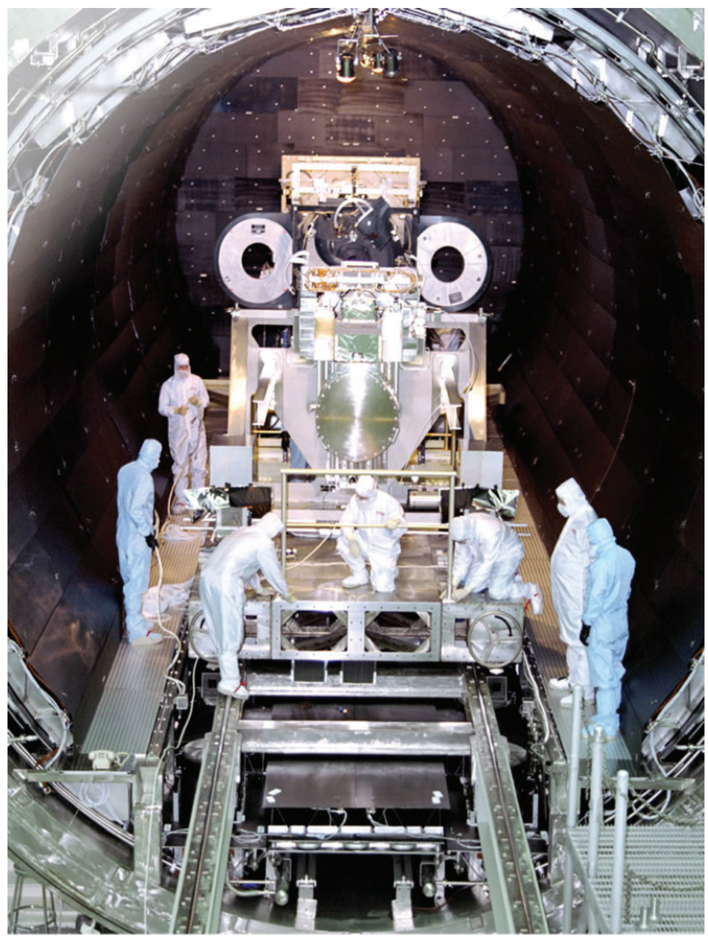
Marshall's pairing of scientific expertise with leading optical systems design engineering enables the Center to have leadership roles in the field of high-energy astrophysics. These roles extend beyond project leadership and scientific investigation, to conceptual studies. In 2013, Marshall astrophysicist Dr. Chryssa Kouveliotou lead the development of a 30-year roadmap for the NASA Advisory Council that will shape the future of the Agency's scientific missions.

Experience

Chandra X-Ray Observatory

The MSFC X-ray Astronomy Team has served as the Project Science organization throughout all phases of the Chandra X-ray Observatory. Members of the team were part of the collaboration that discovered enigmatic and possibly paradigm-shifting flaring at gamma-ray energies from the Crab Nebula and are leading an international effort using Chandra, HST, and a number of ground-based observatories to determine the site from which this flaring occurred.

With its combination of large mirror area, accurate alignment and efficient X-ray detectors, Chandra has eight times greater resolution and is 20–50 times more sensitive than any previous X-ray telescope. Marshall scientist Dr. Martin Weisskopf serves as Project Scientist and was involved in the earliest concept studies and investigations that culminated in the observatory's launch in 1999. Chandra's High-Resolution Mirror Assembly also was tested at Marshall's X-ray Cryogenic Facility (XRCF).

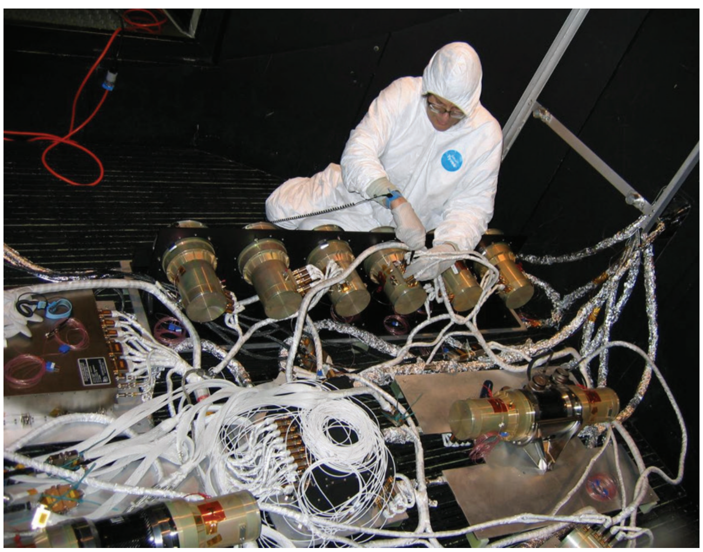


Ground calibration of the Chandra optics and science instruments at XRCF.

Fermi Gamma-ray Burst Monitor

The Fermi Gamma-ray Burst Monitor (GBM) provided astronomers with a tool to study how black holes, notorious for pulling matter in, can accelerate jets of gas outward at relativistic speeds. Physicists are able to study subatomic particles at energies far greater than those seen in ground-based particle accelerators. And cosmologists are gaining valuable information about the birth and early evolution of the Universe. Fermi's wide energy coverage and high sensitivity have provided significant advancements in gamma-ray burst research. In addition, Fermi is also being used to study other high-energy objects within our galaxy, as well as solar flares and short, intense flashes of gamma rays above terrestrial thunderstorms.

To design and test the GBM instrument, Drs. Charles Meegan and Gerald J. Fishman and Marshall leveraged their experience from Compton Gamma Ray Observatory, as well as from developing and integrating other large complex space systems. With scientists and engineers working closely, electromagnetic interference testing and thermal vacuum testing took place at Marshall, as did the integration of flight detectors and electronics. For his contributions to gamma ray astrophysics, including work on Compton and GBM, Dr. Fishman received the 2011 Shaw Prize in Astronomy.



GBM has augmented the science from Fermi by observing gamma-ray bursts from 10 keV to 30 MeV, covering the majority of gamma-ray burst emissions.

Marshall scientists and engineers leveraged the Center's environmental testing expertise to ensure GBM would meet operational requirements once launched.

Science and Optics Collaborating to Overcome Obstacles

The journey of the Chandra X-Ray Observatory began in 1976 with a proposal to build a space observatory capable of collecting and analyzing X-ray emissions from distant sources. With a budget of $2 billion (reduced from $6 billion), researchers created the 11,000-pound spacecraft, 46 feet long and, including its solar panels, 65 feet wide. It isn't the size or cost that makes it one of NASA's Great Observatories. According to the Chandra team, it is the science-driven design, build and operation of the telescope, and a team approach that makes Chandra great.

That approach proved successful in overcoming obstacles in the project. One challenge included manufacturing the largest set of paraboloid-hyperboloid optics and demonstrating that performance would meet requirements, as well as performing x-ray calibration tests in less time and with less money than originally planned.

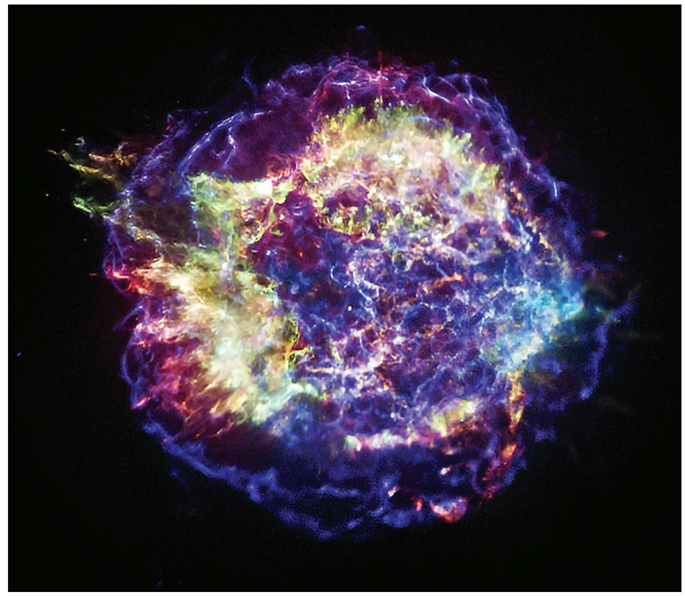
In 1996, the High-Resolution Mirror Assembly arrived at the XRCF for testing and calibration to verify the optics had been built to better than specifications. The performance characteristics of the optics, and the optics in conjunction with the flight instruments, also were calibrated at the XRCF.

After launch, protons reflecting off Chandra's optics caused damage to one of the instrument detectors. Although significant in the early days of the mission, the damage rate slowed when the Chandra team made operational changes to include:

- improvements to the flight software for autonomous protection,
- implementation of ground radiation monitoring operations, and
- the development of an improved model for predicting solar wind and magnetospheric proton fluxes in the Chandra orbit.

The changes resulted in the projected damage of over 10 years being equal to the damage from just the first 8 orbits. The extraordinary first images came just a month later.

With a mission plan of just 5 years, Chandra surpassed its life expectancy and continues to explore the universe, proof of Marshall's ability to use a team approach to develop and integrate large complex space systems as well as to conduct the resulting science.



Cassiopeia A (Cas A), the youngest known supernova remnant in the Milky Way galaxy, has been observed with unprecedented precision over the lifetime of the Chandra Observatory.

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NP-2014-07-92-MSFC
G-62477